Storage of Liquid Manure

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Factsheet

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(Replaces OMAFRA Factsheet, Order No. 94-097, *Storage of Liquid Manure*)

Manure storages are integral parts of the building systems on modern farms. Adequate storage facilities are necessary to handle the larger volumes of manure washwater and contaminated runoff found on today's farms, save nutrients and reduce environmental risks.

Manure is stored in either a liquid storage, a solid storage or a combination solid/liquid storage system.

This Factsheet provides general information about liquid manure storage, including design and safety considerations.

GENERAL REQUIREMENTS OF THE NUTRIENT MANAGEMENT ACT FOR LIQUID MANURE STORAGES

Any new or expanded liquid manure storage on a farm must meet a number of standards as specified in Ontario Regulation 267/03, as amended (O. Reg 267/03), made under the *Nutrient Management Act,* 2002 (NMA).

The following Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Factsheets detail the requirements for the construction of permanent manure storages.

- *Siting Regulations for Manure Storage Facilities,* Order No. 09-061
- *Constructing Hydraulically Secure Liquid Nutrient Storage Facilities,* Order No. 06-035
- *Constructing an Earthen Liquid Nutrient Storage Facility,* Order No. 06-005
- *Constructing a Permanent Concrete or Steel Liquid Nutrient or Runoff Storage Facility,* Order No. 06-001

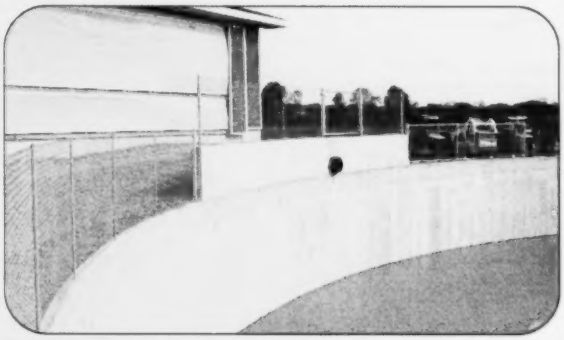

Figure 1. View of a concrete manure storage tank with a 1.5-m (5-ft.) high chain link safety fence.

TYPES OF LIQUID MANURE STORAGES

Large-Diameter Round Concrete Storages

The most frequently constructed storage is a round concrete structure (Figure 1). This style of construction makes the most efficient use of concrete and reinforcing steel. The steel bars resist the outward force of the manure when the tank is full. The concrete wall, due to its circular shape, resists the inward pressure of the earth when the tank is empty.

Circular concrete storages can be built completely below grade, partly below grade or fully above grade. Agitation and pumping is usually provided by a tractor-operated power take-off (PTO) pump positioned over the top of the tank. A partially or fully above-ground tank that uses a tractor-operated pump has pump access ramps. Some operators have boom-operated pumps that allow access over a higher wall.

These storages are 3–5 m (10–16 ft) deep with a depth of 3.6 m (12 ft) being the most common, and up to 48 m (160 ft) in diameter. As this type of storage is normally not expandable, it is best to build them large enough for the foreseeable needs of the farmstead.

Ministry of Agriculture, Food and Rural Affairs

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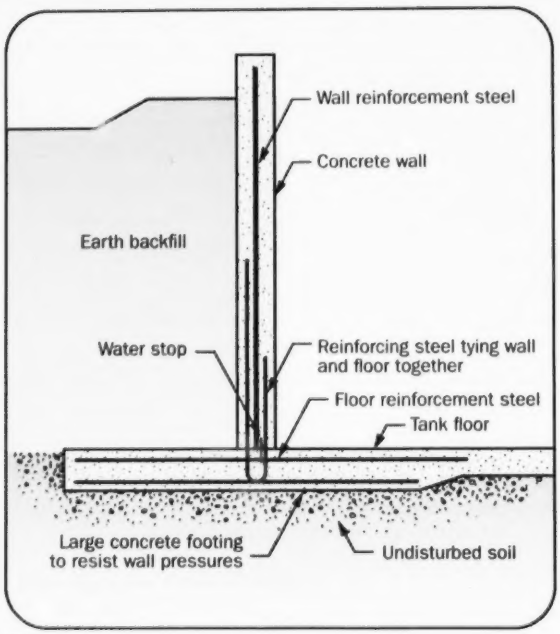

Figure 2. Cantilever wall design.

Rectangular Concrete Storage

Rectangular storages are selected for under-barn storage, when the storage is roofed or when the available area will not fit a circular structure. The straight walls of a rectangular concrete storage must withstand large stresses. Most commonly, these walls are supported with a roof or slat support or with a cantilever or buttress design using the wall as a retaining wall (Figure 2).

An improperly designed or constructed in-ground rectangular storage could fail by collapsing inward when the tank is empty. Ontario Regulation 267/03, as amended, requires all new or expanding manure storage be designed by a engineer.

Above-Ground Concrete Silos

Smaller-diameter above-ground storages are sometimes referred to as manure silos. These silos can have sidewalls greater than 6 m (20 ft) high and have been used to store manure. In the 1970s, many storages of this type were constructed in Ontario. A few are still in use today, especially on swine farms. These silos have limited capacity (less than 1,000,000 L) and are seldom constructed in Ontario today.

Carefully inspect the structure of these silos for leaks, corrosion of the transfer pipes or any other structural problem. Make immediate repairs to any problem, or decommission the tank and replace it with a new manure storage.

Concrete manure storages recommended today are usually 3.3–4.8 m (10–16 ft) deep and placed at least 50% in the ground. This greatly reduces the probability of sudden failure since the lower depth decreases the pressure on the sides of the tank. This type of manure storage can be emptied from the top, eliminating the need for side or bottom discharge piping.

The NMA requires new or expanding storages that are partially or wholly above the ground surface to:

- increase the design load factor for liquid loads to 1.5, or
- provide secondary containment with a capacity of at least 110% of the above-ground portion of the storage, or
- complete the professional engineer's report indicating that a secondary containment system is not required

Circular Glass-Lined Steel Storages

Large-diameter glass-lined steel storages are typically sold as part of a complete system that also includes transfer, pumping and agitation equipment. These systems may be expandable or movable.

Earthen Storages

If proper soil, groundwater and sub-surface soil exist, consider an earthen storage. This rectangular-shaped sloped-wall storage usually has a depth of 3–4.2 m (10–14 ft) with 1:2 (rise:run) side slopes. Note that these sloped sides increase the surface area of the storage, resulting in more precipitation accumulating in it, which can result in a 20% increase in liquid volume. The increase in liquid volume will increase the cost of land-application.

Since an earthen storage structure relies on the properties of the soil and the sealing of the structure's surface to protect the environment, take proper steps to prevent seepage losses. The NMA requires all new or expanding earthen storage structures to be designed by a professional engineer or professional geoscientist. These professionals will provide expertise to ensure that adequate testing and proper construction techniques are used.

O.Reg. 267/03 requires all new earthen storages to have a minimum 0.3 m (12 in.) of freeboard, an interior side slope no greater than 50% and an exterior side slope no greater than 33% except where an engineer's report specifies otherwise. There are further specifications in the regulation regarding the maximum hydraulic conductivity of soils suitable for earthen manure storages as well as minimum depths to groundwater and/or bedrock.

An earthen storage is emptied from a dock using a vertical shaft pump or from the slopes' sides using a long shaft "lagoon pump." Take care while agitating to avoid any erosion of the earthen sides.

In areas where clay content is not sufficient, consider an artificial liner for an earthen storage. This liner may consist of clay, bentonite or plastic. The liner must be adequately protected from turbulence caused during agitation. O. Reg. 267/03, as amended, specifies the minimum standards that must be met if using either synthetic or compacted-soil liners.

Multiple Storage Systems

A series of two or three manure storages used in sequence is considered a multiple storage system. This system partially treats the manure by allowing the solids to settle out from the liquid manure within the first and second storages.

The liquid manure is transferred into the first storage structure from the barn. When the first storage is full, the manure overflows into the second storage. Using this system, the majority of the solids in the manure settle out in the first storage, and the second storage will have low solid matter content. The solid matter content will be even lower in the final cell if there is a third storage included in the system.

Multiple storage systems are used for a number of purposes. A very large storage can be difficult to agitate making it hard to remove all the settled solids. If farms use multiple storage systems, normally only the first storage will require agitation at the time of application.

Flush Barns

Some dairy farms use a flush system. This system uses a multiple storage system where the liquid manure from the last storage is pumped up into an elevated tank. The tank releases the liquid all at once at the top of the livestock alleys. The liquid flushes down the alley, flushing all the manure down to a collection pit. The collection pit is either pumped or drained into the first storage structure. The total capacity of flush storage system tanks is usually 40% larger than a single storage system.

Studies indicate that the elimination of fresh manure reduces pathogen levels substantially. Using multiple storages could be a way to reduce pathogens by allowing an operator to exclude fresh manure from the contents of the storage about to be used for land application.

DEALING WITH EXISTING STORAGES

To ensure a level of protection for surface and groundwater, evaluate existing liquid manure storage structures regularly. Repair urgent problems immediately. In most cases, this may mean hiring an engineer or a qualified third party to ensure that the repair is completed properly.

SIZING LIQUID MANURE STORAGES

An existing or new livestock agricultural operation is phased into the O. Reg. 267/03 requirements when a livestock building or manure storage facility is constructed or expanded. Once phased in, the farm operation will require a "nutrient management strategy" and may require a "nutrient management plan." When a farm is phased in, it must have a minimum of 240 days of storage capacity, unless properly timed manure transfers outside the farm unit are available.

Some farms have constructed storages that will hold more than 240 days of manure accumulation. This increase in storage capacity allows flexibility in the timing to empty the tank during desired crop cycles and weather conditions. One downside of over-building the manure storage is that a larger surface area collects more rainwater, increasing the amount of liquid that must be land-applied. Because of the uncertainty of weather, it is important to have a contingency plan that anticipates situations where the manure cannot be spread as planned.

Table 1. Storage losses from precipitation and free board (240 days of storage)

	Circular Tank		Earthen Manure Storage (120 ft x 120 ft)	
Depth of Storage (ft)	Effective Storage Capacity Depth (ft)	Lost	Effective Storage Capacity Depth (ft)	Lost
8	5.7	29%	4	47%
10	7.7	23%	6	41%
12	9.7	19%	8	37%
14	11.7	16%	9	34%
16	13.7	14%	11	32%

The calculated storage size must include capacity for the manure, any additional liquid planned to be stored in the storage (e.g., runoff, washwater), direct precipitation (if the storage is not covered) and a freeboard (safety allowance). Note that the NMA requires a freeboard of 30 cm (12 in.) for an uncovered storage and 15 cm (6 in.) for a permanently covered, non-slatted storage. OMAFRA's manure management computer program, NMAN, can help with sizing calculations. For information on how to obtain a copy of the NMAN software, visit the OMAFRA website, www.ontario.ca/omafra, or call the Nutrient Management Information Line at 1-866-242-4460.

Storages are normally constructed 3–5 m (10–16 ft) deep. If precipitation can enter the tank, at least 60 cm (2.3 ft) of the tank will be used for precipitation and freeboard. For example, on a 2.4 m (8 ft) deep tank, 35% of the volume will be used for precipitation and freeboard. Many operators prefer a 3.6 m (12 ft) depth (or deeper) since this reduces the precipitation and freeboard requirements to 19% (or less) of the storage volume. Table 1 shows the percentage of losses based on the depth of a circular storage tank and an earthen manure storage facility.

Liquid tanks do not generally have vehicle access ramps into the storage (except for systems requiring access to remove settled sand). In most cases, commercially available agitation systems are capable of removing all the solids from the storage, eliminating the need of an access. A vehicle access increases the initial cost and increases the surface area, allowing more precipitation to enter the storage. Vehicle access also increases risks related to manure gasses.

SITING OF NEW OR EXPANDING STORAGE

The OMAFRA Factsheet, *Siting Regulations for Manure Storage Facilities*, Order No. 09-061, describes all the setbacks that must be considered for the construction of a manure tank. These include:

- well setback (15–100 m (50–328 ft) depending on type and use of well)
- tile drain setback (15 m (50 ft))
- storage foundation drain – If used, an observation/shut-off station is required prior to outputting into a tile drainage system. This station allows an operator to view any flow and be able to shut off the flow from the foundation drain if necessary.
- surface water setback – requires a 50-m (164-ft) flow path from the storage to the nearest surface water.
- flood lines – The storage must be constructed above the 1-in-100-year flood line.

In addition to regulatory requirements, when locating the manure storage, consider the following:

- Locate the storage so as not to interfere with any future expansion plans. In most circumstances, locate the storage along the side of a barn rather than at the end of a barn.
- Locate the storage to be easily accessible and convenient to the fields receiving manure. For a tanker application system, a solid roadbed is necessary to support heavy spreading equipment. Some farmers pump liquid manure from the barn to a storage located away from the barns in the fields. This saves time, labour and damage to laneways during the spreading operation.
- Where possible, locate the storage far enough away from the farmstead home and neighbouring homes to minimize odours. The direction of prevailing winds affects the spread of odours. Screening such as fences or tree lines can help reduce the odour impact of manure storage. It is also important to note that Minimum Distance Separation (MDS) requirements for manure storage differ from siting distances for a livestock barn and depend on the type of storage. For detailed information on MDS, see Publication 707, *Minimum Distance Separation Formulae Implementation Guidelines,* at www.ontario.ca/omafra, or call the Nutrient Management Information Line at 1-866-242-4460.
- In most cases, the MDS calculation is required as part of the building permit process.

- The ground should slope away from all storages to provide drainage of surface water. Avoid vehicle traffic within a distance of the storage equal to the depth of the storage below grade, unless the access is on a reinforced concrete ramp or platform designed to support or distribute the weight.

COMPARING UNDER-BARN TO OUTSIDE STORAGE

The liquid manure storage can be located directly under the barn or outside the barn. Slatted storages with livestock housing on top minimize the steps required to transfer manure from the barn to the storage. In addition, under-barn storage facilities can be closer to neighbours than separate, uncovered external storages (based on MDS calculations). However, under-barn storages are more difficult to ventilate, especially for agitating.

Storing manure under the barn limits your options for manure treatment systems such as biogas systems. In general, it is best to use fresh manure in treatment systems. In addition, a deep under-barn storage may become under-utilized if manure has to be regularly pumped out of the storage and into the treatment system. Avoid under-barn storage if you are considering a biogas system in the future. For more information on biogas systems, see the OMAFRA Factsheet, *Anaerobic Digestion,* Order No. 07-057.

Some livestock barns are designed with short-term storage under the barn and long-term storage in an outside tank (Figure 3). This may consist of a partially slatted floor system or a shallow pit under the barn. The size of under-barn storage is typically matched with an all-in-all-out production cycle (or shorter time period), and manure is transferred to long-term storage through a pull-plug, gravity-flow system or by flushing, using recycled liquid supernatant.

A liquid manure storage located separate from the barn is the most common. Normally, this manure storage is built close to the barn to minimize manure transfer costs. However, some operations now locate the long-term storage away from the barn, in the centre of the spreading landbase.

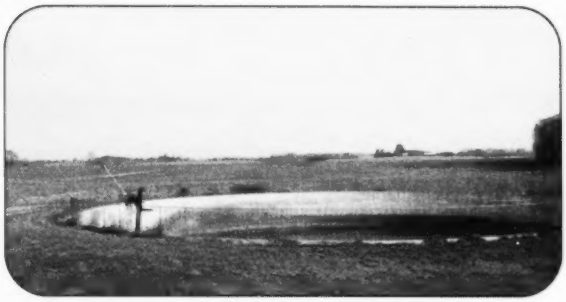

Figure 3. View of long-term outside storage.

COVERED OR OPEN-TOP STORAGE

Covering the storage reduces odour around the farmstead as well as the amount of precipitation entering the tank, resulting in a 15%–35% reduction in liquid volume. Economics, siting requirements and the owner's preference influence the choice of cover.

However, a conventional concrete cover may double the construction cost compared to an open-top tank.

Choose a cover structure that is resistant to the corrosive gases trapped by the cover. Non-protected metal material in truss-type roofs will quickly deteriorate. Do not expose reinforcing rods in concrete covers to the manure gases.

The trapped gases produced during agitation under the storage cover may unintentionally be pulled from the tank to the barn through the transfer pipes (Figure 4). Install proper gas traps to prevent movement of gas. A manually closed valve is NOT adequate.

Note that O.Reg. 267/03 s.78.(1) and s.78.(2) require that covered manure storages be either mechanically or naturally ventilated to eliminate corrosive, noxious or explosive gases. If tractors or other vehicles can drive on a tank cover, install a cover designed to handle the heaviest possible loads. Remember that this cover is there for a long time; plan for heavier equipment you may acquire in the future. If a cover with an unknown design is on a farm, it is wise to assume that it will not hold the load. Fence this storage to eliminate vehicular access.

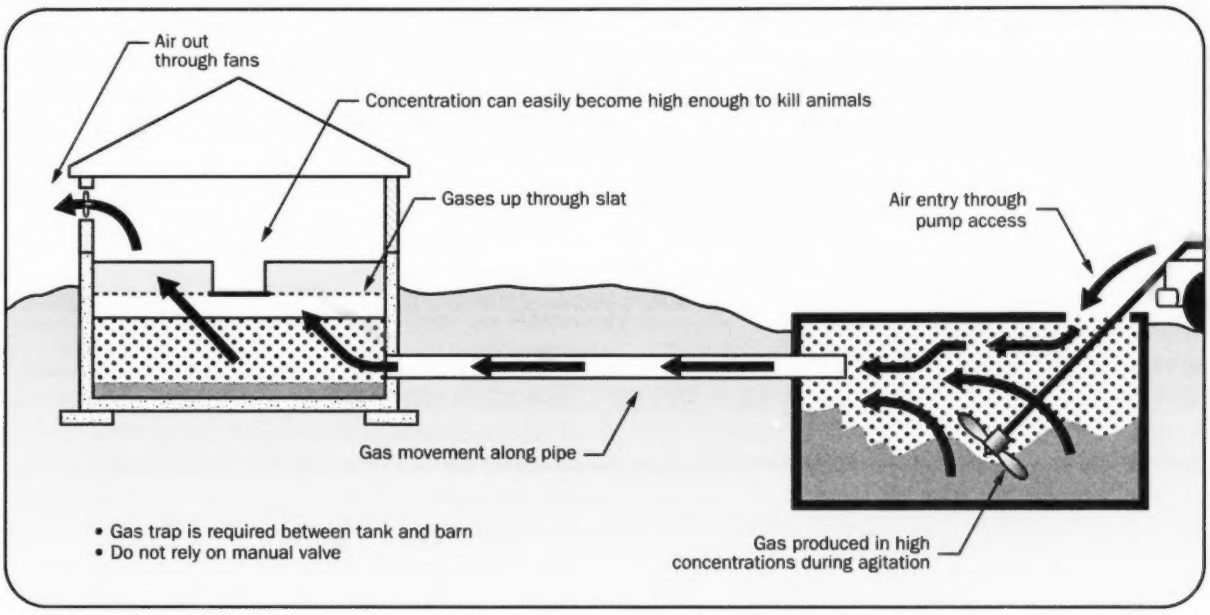
Air out
through fans
Concentration can easily become high enough to kill animals
Gases up through slat
Air entry through
pump access
Gas movement along pipe
• Gas trap is required between tank and barn
• Do not rely on manual valve
Gas produced in high
concentrations during agitation

Figure 4. Movement of manure gas from tank to barn. Always install a gas trap between tank and barn.

Floating covers may be another option. The cover could be a plastic or geo-textile material, or organic material, such as straw, blown on the surface. For flexible covers, there are negative-pressure cover systems and positive-pressure cover systems. The negative-pressure cover system consists of an air-tight cover sealed around the edges of the tank, with a vacuum fan withdrawing air from between the cover and the surface of the liquid manure (Figure 5). This vacuum holds the cover down, preventing the wind from lifting or damaging the cover. The positive-pressure cover system is similar, except the air fan is reversed to blow air under the cover and inflate it like a balloon. It acts much like an air structure used to cover tennis courts or sports fields. Both systems are effective in reducing odours from the storage.

Organic material covers consist of organic materials that cover the total surface of the storage. This type of cover acts like a biofilter and reduces odours emitted from the storage. Chopped barley straw blown over the surface is one example of an organic cover. In some types of farm operations, manure storages will have moderate input of bedding from the barn. This bedding will float to the surface of the tank and develop a surface crust after a short period of operation. This crust acts like an organic manure storage cover and reduces odours from the storage. Organic covers are temporary; they are chopped up and mixed in with the manure during storage agitation. Insufficient coverage may result in the organic cover being blown away or sinking into the liquid.

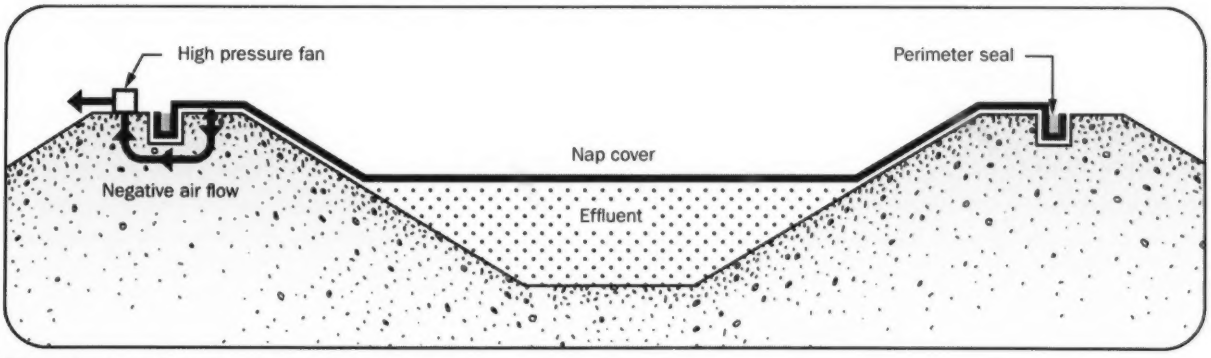

Figure 5. Negative-pressure manure tank cover.

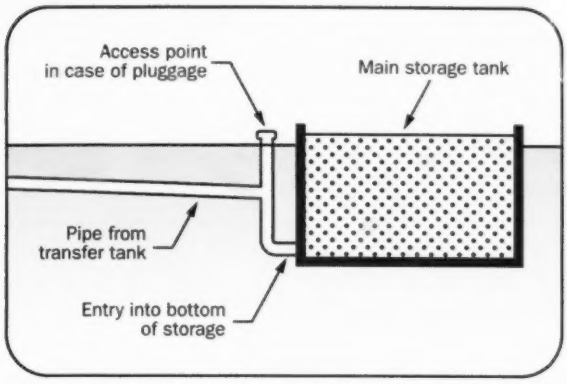

Figure 6. Manure entering bottom of tank prevents freezing.

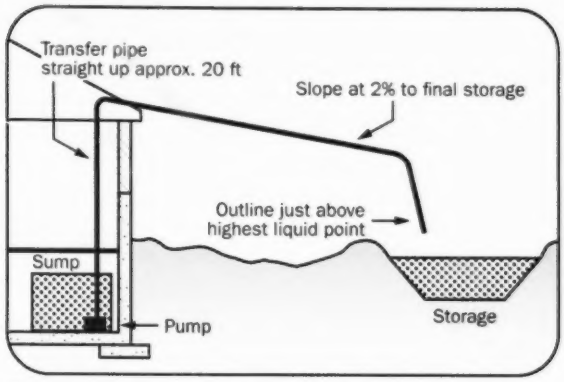

Figure 7. Above-ground pipe for anti-backflow control.

TRANSFER SYSTEMS

All storages separate from the barn need a transfer system to move the manure to the storage. The simplest and most common approach is a gravity-flow pipe system, which requires the bottom of the tank to be set at least 3 m (9 ft) below the lowest point or gutter in the barn. This may not be feasible if there is a high water table or bedrock level. If highly dilute manure is used (e.g., swine manure or contaminated runoff), a 20–30-cm (8–10-in.) diameter transfer pipe is normally adequate. If this pipe is continuously trickling, manure can freeze at the tank; locate the pipe at the bottom of the tank to prevent this (Figure 6).

If thicker manure is used (e.g., dairy manure with some bedding), use a larger diameter transfer pipe (up to 90 cm (3 ft) diameter). Avoid sharp corners or transitions in the pipe to reduce the chance of plugging. For large diameter pipes, a 60-cm (2-ft) minimum fall is required between the lowest gutter level in the barn and the top elevation of the tank.

Another way of handling thick manure is using a separator to remove the solids. The remaining liquids can be handled in a similar manner to highly dilute manure. An anaerobic digester will also remove solids allowing for easier transfer of manure.

If there are inadequate conditions to allow a gravity-flow system, use a pump transfer system. The most common transfer system for highly dilute manure (swine with no or little bedding) is a 5,000–20,000-L (1,000–4,000-gal) transfer tank located at the end of the barn gutter. When this tank is full, a 3–7 horsepower electric pump transfers the liquid to the main tank. If there are settling problems in the transfer tank, design the pump to agitate before transfer.

When transferring thicker manure, use a larger transfer tank (20,000–100,000 L) with a tractor-operated transfer pump. The tank is fully agitated bi-weekly and transferred to the main storage. Several systems allow some diluted liquids to flow back from the main tank after transfer to allow easier agitation the next time.

Large piston pumps are also used to transfer thicker manure. Make sure adequate electrical power is available to operate both the stable or alley cleaner and the transfer pump.

If the final storage holds liquids at a higher level than the lowest point in the barn, take proper precautions to avoid any possibility of inadvertent backflow. Mechanical, one-way valves are generally not adequate, since debris in the manure may keep the valve open. The safest method is to have an air gap between the outlet of the transfer pipe and the main storage.

The most common method of transferring to a higher tank is to pump straight up approximately 6 m (20 ft) and then have the pipe slope at a 2% grade to the tank (Figure 7). When the pump completes a cycle, some of the liquid drains back into the transfer tank, and the remaining liquid drains to the main storage. This avoids liquid freezing in the pipe.

A second option is to construct an underground transfer pipe to the main storage with a riser elbow and a vent pipe at the transfer tank. A portion of riser pipe may remain full at the transfer tank and must be protected from freezing (Figure 8). O. Reg. 267/03 requires both a primary shut-off valve and a secondary shut-off valve where there is any opportunity for backflow to the pump or pump-out chamber.

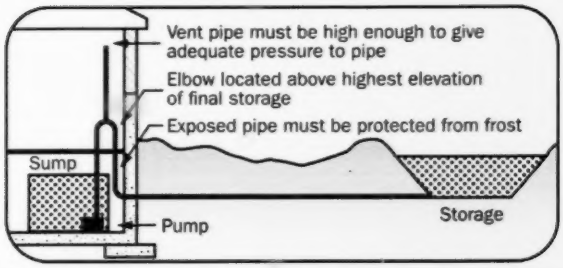
Vent pipe must be high enough to give adequate pressure to pipe
Elbow located above highest elevation of final storage
Exposed pipe must be protected from frost
Sump
Storage
Pump

Figure 8. Below-ground alternative for anti-backflow control.

O. Reg. 267/03 requires that liquid manure transfer piping systems be installed using specifically designed and compatible gasketted fittings such as tees, saddles, end caps and elbows. Where the pipe enters into the floor or wall of the manure storage, a flexible watertight gasket or membrane must be installed to serve as an anti-seepage collar. An engineer must design and inspect the installation for all new or expanded transfer systems. The engineer must sign an Engineers Commitment Certificate indicating that the liquid transfer system will be properly designed, installed and a general review be completed. This completed form plus a completed NMS/P are required to obtain a building permit for the structure.

PREVENTATIVE MAINTENANCE

All farms should have preventative maintenance plans that include all maintenance schedules for machinery, barn mechanical components, barn, field tiles and outlets and manure structures, etc. Conduct a preventative review for the manure storage structures at least once a year. This preventative maintenance plan can include the examination of the concrete tanks for cracks, fence and gate conditions and functionality, checking inlet pipes and the concrete condition around them, valves and transfer pipes if included, etc. If any problems are found with the manure storage structure, hire a specialist to examine and correct the problem. One of the best times to conduct preventative maintenance on the manure storage structure is when the manure is completely removed from the storage.

SAFETY

Never enter a liquid manure tank without taking proper precautions for confined space entry (contact the Farm Safety Association for information on confined space entry, www.fsai.on.ca).

To address the safety concerns created by construction of a liquid manure storage system:

- Enclose all open liquid manure storages with a permanent safety fence or wall extending to not less than 1.5 m (5 ft) above adjacent grade or floor level and having gates with latches to deter access by children and livestock.
- Install covers over access ports of all manure tanks with tops. These covers should weigh at least 20 kg (45 lb) so that children cannot lift them. A chain bolted to the cover and to the tank lid will prevent the cover from being removed from the area, or from being lost if it should fall into the tank.
- Install a sign warning of the danger due to toxic gases at every access to a liquid manure storage tank or under-floor manure transfer chamber.
- Where an outside tank is joined to the barn by a pipe or gutter, install gas traps to prevent dangerous gases from entering the barn.
- To discourage entry, do not install permanent ladders in a manure tank.

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